Best Practices in Steam System Management

Fred L. Hart, U.S. Dept of Energy
David Jaber, (formerly with) Alliance to Save Energy

Achieving operational excellence is a continuous task for all manufacturers working to reduce costs and keep their plants profitable. Luckily, many opportunities exist for industrial plants to cut costs without jeopardizing jobs or the environment. For example, over 50 percent of the input fuel used by the U.S. manufacturing sector is used to generate steam. More importantly, in a typical facility, a 20 to 30 percent improvement in steam system efficiency, i.e., the ability to meet their steam needs with 20 to 30 percent less fuel, is possible. At an estimated annual cost of $18 billion for fuel, alone, in the 33,000 boilers used by industry, reducing steam fuel use can improve profits nationally. [1] The chemicals industry can particularly benefit as it is very steam intensive; steam production accounts for over 50 percent of fuel used by the sector. Other sectors which really benefit through steam system improvements include pulp and paper, food processors, steel mills, petroleum refining, and textiles.

Common areas in which to look for savings opportunities in steam generation, distribution, end use and recovery are outlined below.[2] By determining which are the most appropriate at a given plant, a good start can be made on improving the productivity and reliability of the plant, while cutting unnecessary costs.

Steam Generation

Demand Reduction

The boilers may well be producing more steam than is needed for the end uses. Evaluation of demand is especially important when downstream improvements such as insulation and condensate return are implemented - lower loss means lower generation needs. At Nalco Chemical Company's Clearing Plant in Bedford Park, Illinois, a process engineer determined that a steam header pressure of 125 psig was no longer necessary due to changes in the some of the plant's processes. A team of personnel from the maintenance, utilities, and production departments evaluated the feasibility of reducing the header pressure and decided to incrementally decrease header pressure while monitoring the effects of this change on system performance.

The pressure was reduced twice, first to 115 psig, and then to 100 psig. After determining no detrimental impacts on system operation, Nalco now operates the system at 100 psig, resulting in annual energy savings of 8 percent, far exceeding initial expectations, and saving $142,000 annually along with reduced carbon emissions. For this work, the plant received a 1997 Chemical Manufacturers Association Energy Efficiency Award.[3]

In addition to a straight boiler generation reduction, a specific end use pressure might be reduced. As part of their Operational Excellence Program, Vulcan Chemicals, a business group of the Vulcan Materials Company, implemented a process optimization project involving two chloromethane production units. This four-month project required no capital investment and resulted in a reduction in process steam demand and significant cost savings. Vulcan lowered the steam system pressure in the first distillation column from 35 to 26 psig. This gave them a lower condensing temperature that requires less reflux during component separation. Average reboiler steam demand per unit of product decreased by almost 6 percent and resulted in yearly cost savings of $42,000. This plant also received a Chemical Manufacturers Association Energy Efficiency Award in 1997 for the project.[4]

Boiler Tune-Up

The major areas of opportunity in boiler tune-up encompass excess air and blowdown optimization. Optimum excess air minimizes stack heat loss from extra air flow while ensuring complete fuel combustion. Stack temperature and flue gas oxygen (or carbon dioxide) content are the primary indicators of the appropriate excess air level; an adequately-designed system should be able to attain a 10 percent excess air level. The required action is to monitor flue gas composition regularly with gas absorbing test kits or computer-based analyzers. Highly variable steam flows or fuel composition may require an on-line oxygen analyzer, also called oxygen trim control.

Optimizing boiler blowdown helps keep steam quality high for effective production, while reducing fuel and water treatment expenses. Blowdown rates typically range from 4 to 8 percent. Relatively pure feedwater may require less, where high solids content water requires more. Extensive operating practices have been developed by an AIChE sister organization, the American Society for Mechanical Engineers. These blowdown practices depend on operating pressures, steam purity needs, and water deposit sensitivity of the system. For best blowdown results, investigate the ASME guidelines and also look into continuous blowdown control systems to help maintain optimal blowdown levels.

Clean Heat Transfer

Scale build-up can cause safety hazards from heat exchanger tube failure and boiler metal overheating, in addition to excess fuel use of up to 5 percent. Heat transfer surfaces can be kept relatively clean by pretreating boiler makeup water with water softeners, reverse osmosis, and/or demineralizers, treating returned condensate, if needed, and adopting proper blowdown practices. Remove existing scale either mechanically or through acid cleaning. It can also be useful to consult a specialist in water treatment.

Auxiliary Equipment

In addition to the automatic blowdown control system and oxygen trim control already mentioned, other equipment which can increase boiler efficiency include economizers, blowdown heat recovery systems, and controls. Economizers transfer heat from the flue gas to the feedwater, and are appropriate when insufficient heat transfer (assuming heat transfer is clean of scale) exists within the boiler to remove combustion heat. Good boiler candidates are those above 100 boiler horsepower. Determine the stack temperature and minimum stack temperature to avoid corrosion (250° C if natural gas is the fuel; 300° C for coal and low sulfur oils; and 350° C for high sulfur oils) after tuning boiler to manufacturer specifications. This will help indicate whether or not an economizer makes sense economically in the plant.

Blowdown heat recovery systems preheat boiler make-up water using the blowdown water removed and make sense in continuous boiler blowdown systems. Blowdown waste heat can be recovered simply with a heat exchanger, or in a flash tank. For controls, an oxygen trim control system provides feedback to the burner controls to automatically minimize excess combustion air for an optimum air to fuel ratio. This can result in fuel savings of 3 to 5 percent and is useful where fuel composition is highly variable.

Steam Distribution

Steam Leaks

Steam leaks can be dangerous in higher-pressure systems, above and beyond the significant energy waste they represent. Steam leaks are often found at valve stems, unions, pressure regulators, equipment connection flanges, and pipe joints. The first step is to conduct a steam leak survey. Large steam leaks are visible and ultrasonic detectors can identify even very small leaks. Tag the leaks and determine which can be repaired by your maintenance staff and which require service technicians.

Steam Traps

In steam systems that have not been maintained for 3 to 5 years, from 15 to 30 percent of traps may have failed, and regularly-scheduled maintenance should reduce this to under 5 percent of traps. The cost of one medium-sized steam trap that failed to open in an average pressure system might be $3,000 per year and more. Traps can be tested by a range of means, including visual inspection, listening to the sound, pyrometers, and ultrasonic and infrared detectors.

For optimum performance, establish a regular trap inspection, testing, and repair program that includes a reporting mechanism to ensure replicability and provides for documenting energy and dollar savings. Velsicol Chemical's Chestertown, Maryland, facility implemented a preventive maintenance (PM) program to identify energy losses in their steam system. Velsicol's PM program inventoried the plant's steam traps, trained system operators to identify failed traps, and improved communication between maintenance and production personnel so that failed traps were quickly repaired or replaced. This program also identified improperly sized traps or traps of the wrong type and planned their replacement.

Implementing the program saves Velsicol over $80,000 annually at an initial cost of just $22,000. It also reduced energy consumption on a per production unit basis by 28 percent, and had a payback of just over 2.5 months. The plant received a 1997 Chemical Manufacturers Association Energy Efficiency Award for the project. The effort reduced annual CO_2 emissions by 2,400 tons. Yet another benefit was the reduced worker exposure to treatment chemicals.[5] A large Rohm and Haas methyl methacrylate plant in Kentucky, implementing a similar program, saved nearly $500,000 each year.

Insulation

Insulation helps ensure proper steam pressure for production and can reduce radiative heat loss from surfaces by 90 percent.[6] The Department of Energy (DOE) Industrial Assessment Center program demonstrated a savings potential ranging from 3 percent to as high as 13 percent of total natural gas usage on average through insulation installation. The optimum insulation thickness can be calculated with the DOE 3E+ software program. Depending on pipe size and temperature, needed insulation thickness may range from one inch to over eight inches. For steam systems specifically, common insulating materials include fiberglass, mineral fiber, calcium silicate, and cellular glass. Material choice depends on moisture, temperature, physical stress, and other environmental variables.

Appropriate actions include: first, insulate steam and condensate return piping, boiler surfaces, and fittings over 120 degrees Fahrenheit; second, conduct a survey of the overall facility steam system every five years for deteriorated and wet insulation; and third, repair or replace damaged insulation. As an example, Georgia Pacific's plywood plant in Madison, Georgia, insulated several steam lines leading to its pulp dryers. Using 3E+, they determined an optimal insulation for their steam lines and installed mineral fiber insulation. Georgia Pacific found this made their work environment safer and improved process efficiency. Together with steam trap maintenance, the plant reduced its fuel costs by roughly one-third over the year and also lowered emissions — 9.5 million lbs. of carbon dioxide (carbon equivalent), 3,500 lbs. of SOx, and 26,000 lbs of NOx on an annual basis.[7]
Steam Recovery

Condensate Return

Return of high purity condensate reduces boiler blowdown energy losses and makeup water. This saves 15 to 18 percent of the fuel used to heat the cool makeup water, saves the water itself, and saves treatment costs and chemicals. Reduced condensate discharge into the sewer system also reduces disposal costs. Repair condensate return piping leaks for best results. If the condensate return system is absent, estimate the cost of a condensate return system and install one if economically justified.

Flash Steam Recovery

When the pressure of saturated condensate is reduced, a portion of the liquid "flashes" to steam at a lower pressure. This can be intentionally done to generate steam or unintentionally. Flash steam contains anywhere from 10 to 40 percent of the energy content of the original condensate depending on the pressures involved.

Often the steam is vented and lost; however, a heat exchanger can be placed in the vent. Inspect vent pipes of receiver tanks and deaerators for excessive flash steam plumes and install heat exchangers.

As an example illustrating the economics of steam and condensate recovery, the Bethlehem Steel Burns Harbor plant returned a portion of its warm condenser cooling water exhaust stream to the boiler feedwater and rerouted low pressure waste steam into a steam turbine generator. This along with a turbine rebuild results in annual savings of approximately 40,000 MWh of electricity, 85,000 MMBtu of natural gas, and nearly $3.3 million. With a cost of $3.4 million more than a standard maintenance overhaul, the project had a simple payback of just over one year.[8] The project also reduced high-temperature water discharge into the harbor and decreased coke-oven and blast-furnace gas emissions by 27,200,000 lbs. of carbon equivalent, 294,000 lbs. of SOx, 370,000 lbs of NOx, 11,600 lbs. of PM_{10}, 1,450 lbs of VOCs, and 14,000 lbs of CO.

Putting It All Together

The above tips point out the power of taking a systems approach to energy management. Returning condensate and recovering heat from the end of the process makes true steam demand assessment, clean heat transfer maintenance, environmental emissions control, and fuel use minimization at the boiler easier. Pursuing the systems approach can be facilitated by using the resources of the DOE Office of Industrial Technologies, which is the source of most of the above guidance. DOE assistance focuses on helping industry in developing and adopting energy-efficient technologies and practices through voluntary technical assistance programs on plant-wide energy efficiency. Areas of focus include industry-specific emerging technologies, industrial steam systems, electric motors, drives and pumps, industrial compressed air systems, and combined heat and power systems.

In conjunction with the Alliance to Save Energy and industry steam experts, a network of resources has been established to help steam-using industrial plants adopt a systems approach to designing, installing and operating boilers, distribution systems, and steam applications. Benefits of the systems approach include lower operating costs, lower emissions, increased plant operation reliability, and increased productivity. Specific resources include:

- Tip sheets.
- Case studies.
- Answers to technical questions.
- Databases of training opportunities, technical tools, references and standards.
- Workshops which bring together public manu-facturing resources, private-sector energy management assistance, and peer networking opportunities.
- Plant-wide assessment opportunities.
- Technical papers.
- Project financing guidance tools.
- Publicity and awards through case study data.

Existing resources are available through the Industries of the Future Clearinghouse ((800) 862-2086, clearinghouse@ee.doe.gov), the website (www.oit.doe.gov/bestpractices/steam) and the OIT resource room at (202) 586-2090. These resources also include a Sourcebook providing a comprehensive steam system overview and references and a Steam Scoping software tool providing guidance on how to profile and assess steam systems.

Case studies in particular have a lot of power, and many of these are specific to the chemical industry. Internally, case studies help foster success replication for other company facilities as well as achieve internal company recognition. Externally, the company can receive recognition as an industry leader. DOE is available for assistance in case study documentation.

Conclusion

Too many manufacturing facilities are not achieving their full potential because of poorly operated and maintained steam systems. Steam efficiency lies at that rarely visited intersection of improved economic performance, greater energy-efficiency, and environmental benefit. By taking advantage of available public and private energy management resources, any manufacturer can benefit.

Continuous improvement and maintenance of steam system efficiency through monitoring and maintenance leads to greater reliability, cost effective production and price competitive products. The following steps help pursue the systems approach: 1) Walk through your entire steam system by performing an audit, 2) Document the audit results and make appropriate improvements as outlined here; and 3) Develop and implement a program for ongoing maintenance. The long term benefits of system efficiency require continuous improvement through proper operating and maintenance practices. This prevents a system from degrading into a mode of poor performance.

Heightened awareness of operating costs and performance implications is key to understanding the importance of steam system management. Additional ways to discover and capture savings opportunities are by sharing experiences within and outside the company, and increasing interaction between facility operations and management to reconcile production and engineering facts with the financial and corporate priorities.
For more information contact:

Fred Hart
U.S. Department of Energy
Email: fred.hart@hq.doe.gov
Phone: (202) 586-1496

References

1. Unpublished research of the Alliance to Save Energy, 1999. Calculated from GRI boiler data and *Monthly Energy Review* fuel cost data.
2. The suggestions and facts used in the savings opportunities areas come from the U.S. Department of Energy Energy Tips tip sheet series and can be consulted for further information.
3. U.S. Department of Energy, April 1999. *Reducing Steam Header Pressure Provides Attractive Operating Cost Savings*, 2 pp.
4. U.S. Department of Energy, July 2000. *Reducing Steam Pressure Saves $42,000 Annually At Vulcan Chemicals,* DOE/ORNL-002, 4 pp.
5. U.S. Department of Energy, April 1999. *Improved Steam Trap Maintenance Increases System Performance and Decreases Operating Costs,* DOE/ORNL-003, 4 pp.
6. U.S. Department of Energy, September 1995. *Industrial Insulation for Systems Operating Above Ambient Temperature,* ORNL/M-4678, 12 pp.
7. U.S. Department of Energy, November 1998. *The Challenge: Increasing Process and Energy Efficiency at a Plywood Plant,* ORNL/SC-CS2, 4 pp.
8. U.S. Department of Energy, April 1999. *The Challenge: Improving Steam Turbine Performance at a Steel Mill,* DOE/GO-10099-763, 4 pp.